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STUDIES ON CERTAIN GENERALISED VENDOR-BUYER INTEGRATED INVENTORY SYSTEMS

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Introduction

Inventory theory has been one of the most successful Operational Research techniques applied in business, industry and public sector. Inventories are resources of any kind having an economic value and have an extremely important role in the economy of any country. Primarily, inventory is held for transaction purposes. Today's inventory is tomorrow's consumption. Inventory is held for smooth running of the organization. Inventory may be an idle stock for the time being but it will be used as and when required. The inventory problems deal with the optimal replenishment/production plans of items which are procured/produced and stored for meeting future demands. In a large scale production; raw materials, labour, machines, spare parts or finished goods etc. may be inventories stocked in order to meet an expected demand.

In real life situations, the stock level of an item in an inventory is depleting due to its demand rate. The demand rate for an item is an important factor since the inventory position changes in response to customers' demand. Demand rate may be deterministic(a constant and known or varying with time) or probabilistic (a random variable which follows known probability distribution) throughout the entire time horizon.

Another cause for decreasing inventory level is deterioration of items. Deterioration of items in the form of direct spoilage or gradual physical decay in the course of time is a realistic phenomena and hence it should be considered in inventory modeling. Food items, pharmaceuticals, chemicals, blood, drugs etc., are some examples of such products. Some items deteriorate constantly with time, while deterioration of some other items could be modeled with probability distributions.

The inventory system can be classified as a single-item or multi-item, a single-stage or multi-echelon system. The inventory of only one type of an item is called as a single-item inventory system; where as the inventory of more than one type of an item is called as a multi-item inventory system. Similarly, if the item is stored at a single location, it is called as a single-stage inventory system and if the item is stored at more than one location, it is called as a multi-echelon inventory system.

Costs associated with inventories

Inventories cannot be held without cost. The major costs associated with

inventories are holding cost, set-up cost and shortage cost.

- Holding cost - It is also known as maintenance cost, carrying cost, storage cost or running cost. This cost is directly proportional to quantity in stock and duration of stock.

- Set-up cost - It is also known as ordering cost or cost of replenishment. It includes fixed cost that is involved in placing a new order or starting a new production run. It does not depend on the quantity of goods ordered.

- Shortage cost - It is also known as the penalty cost or stock-out cost. This cost comes into picture when demand exceeds supply. It may be as a loss of goodwill or loss of business. Shortage cost is directly proportional to quantity of shortage and duration of the shortage. In such cases we may have to pay unusually high price which leads to loss.

The algebraic sum of all the afore mentioned costs form the total cost of the inventory system. All the three costs are related to each other. An attempt to decrease (or increase) one cost would result in increase (or decrease) in the other costs.

Hence main objectives of any production planning and inventory management system are to determine the optimal order quantity and the optimal replenishment period with minimum system cost.

Basic inventory models

There are two basic types of inventory models - Deterministic inventory model and Stochastic inventory model

- Deterministic inventory model - In this case; demand is assumed to be fixed, known in advance and uniform throughout the period.

- Stochastic inventory model - In many practical situations, demand may not be exactly known. It may be uncertain throughout the period and hence it is a random variable. In such cases, variable demand follows a known probability distribution. Inventory models involving the probability distribution of future demand, in which distribution is same for each replenishment period, is known as stochastic inventory models.

Analysis of an inventory system includes the following steps:

(i) Determination of the properties of the system.

(ii) Formulation of the inventory model.

(iii) Analysis of the model.

(iv) Sensitivity analysis.

The level of inventory depletes according to the demand for the items. Therefore, 'when to order' and 'how much to order' are the two important decision rules, which constitute inventory policy. There are two types of inventory policies: periodic review policy and continuous review policy. In a periodic review policy, the inventory level is observed at discrete, equally spaced regular intervals of time and a decision regarding replenishment of units will be considered. In a continuous review policy, the inventory level is observed continuously over time and a decision regarding replenishment of units will be considered.

Nowadays, because of digitalization the inventory level can be reviewed instantaneously and hence, in most of the cases, a continuous review policy can be used.

Mathematical formulation of an inventory model

Study of the inventory system could be made easy by developing an inventory model suitable to represent a real inventory system. A simple mathematical formulation of an inventory system, which can be used in most general situations, as per Sivazlian and Stanfel (1975) is presented in Chapter 1.

Need and importance of vendor-buyer relationship

In today's global markets, because of increased competition, individual and independent entities can not compete as solely and can not survive for long run in business. It is better to work together as a supply chain to manage inventories more efficiently.

Due to rising costs, shrinking resources, shortened product life cycle, increasing competitive pressure and quicker response, much attention has been

paid to the collaboration between the members of the supply chain. In a supply chain inventory system, buyer purchases products from vendor. The buyer may be a regular purchaser of goods from vendor based on long term agreements. The new global market requires long term close cooperation between vendor and buyer for their successful business. Trust between them would develop over time due to various factors, such as, quality of items, adherence to delivery schedule, permissible delay in payment etc.

Good relationship between the vendor and buyer may allow for the sharing of information, forecasts and knowledge between them. Close cooperation between them can result in more cost effective production and distribution as well as a faster response to customer's demand which creates a beneficial environment for them. Team work of vendor and buyer leads to considerable success in business. Hence coordination between vendor and buyer is an important way to gain competitive advantage in supply chain management as it lowers supply chain cost.

Decision regarding the shipment schedule and the size of shipment must be taken jointly by both vendor and buyer. The integration between them would result in reduction of wastage. The vendor-buyer integrated inventory model aims to determine the number of shipments from vendor to buyer, the shipment schedule and the size of shipment quantity in each shipment which minimizes the integrated total cost of the inventory system.

Review of Literature

Considering the vast number of research publications related to inventory models/problems, we have focused the literature survey on certain key areas related to inventory models, viz., models with deterioration, models with different types of demand and vendor - buyer models. Several researchers have developed EOQ (Economic Order Quantity) models with different assumptions on demand and deterioration rate, with or without shortages, partial backlogging or complete backlogging. Hariga (1995) developed an EOQ model for deteriorating items with time-varying demand and with a numerical example showed that the inventory model with shortages and complete backlogging is considered to be better economically. Papachristos and Skouri (2000) have studied an EOQ inventory model where items deteriorate at a constant rate, demand rate is dependent on time and partial backlogging of shortages. Wee and Law (2001) presented a deterministic inventory model for an item where demand rate is dependent on price, deterioration rate is vary-

ing with time and complete backlogging of unsatisfied demand. Wu (2002) presented an EOQ inventory model in which inventory is depleted by both time varying demand rate and Weibull deterioration rate. Inventory cycle is started with shortages and ended without shortages. Amutha and Chandrasekaran (2013) have studied an inventory model with three parameter Weibull deterioration rate and price dependent demand rate.

Many researchers have analysed EOQ models with two-phase ramp-type demand rate with different assumptions on deterioration rate and shortages. Manna and Chaudhuri (2006) developed an order level inventory model with ramp type demand rate and time dependent deterioration rate. The authors assumed that the time point at which the demand stabilizes is occurring before the production stops and developed two models - with and without shortages. Skouri et al. (2011a) extended the work of Manna and Chaudhuri (2006) by considering different conditions for stabilization of demand rate.

Jain and Kumar (2007) developed an EOQ model with ramp type demand rate, Weibull deterioration rate, with shortages being completely backlogged. Skouri et al. (2009) considered an inventory model with ramp type demand rate, Weibull deterioration rate and partial backlogging of unsatisfied demand under two different policies viz., starting with no shortages and starting with shortages. Jain and Kumar (2010) derived an EOQ inventory model with ramp type demand rate, three parameter Weibull deterioration rate starting with shortage and shortages being completely backlogged. Valliathal et al. (2013) studied the inflation effects and time discounting on an EOQ model with ramp type demand rate and Weibull deteriorating/ameliorating items.

Skouri et al. (2011b) proposed an order level inventory model for deteriorating items with general ramp type demand rate under permissible delay in payments by allowing shortages with partial backlogging. Singh and Sharma (2013) developed an inventory model for deteriorating items with ramp type demand rate allowing shortages with partial backlogging. Panda et al. (2013) developed an inventory model for non-instantaneous deteriorating items with price and time dependent ramp type demand rate.

Many researchers have discussed EOQ models with trapezoidal type demand rate with different assumptions on deterioration rate and shortages. Panda et al. (2008) discussed an order level inventory model for deteriorating items with three phase time-dependent ramp-type demand function. Cheng and Wang (2009) proposed an inventory replenishment policy for deteriorating items with trapezoidal type demand rate allowing shortages. Cheng et al. (2011) derived a mathematical model for time dependent deteriorating

items with trapezoidal type demand rate and partial backlogging of unsatisfied demand. Chuang et al. (2013) extended the work of Cheng et al. (2011) considering the pricing policies in marketing. Chaudhary and Sharma (2013) developed an inventory model with Weibull deterioration rate and trapezoidal type demand rate for items in the inventory. Wu et al. (2016) discussed two inventory systems starting with and without shortages with trapezoidal type demand, time dependent deterioration rate and partial backlogging. Aliyu and Sani (2018) developed an inventory model where deterioration of items in the inventory is a linear function of time and demand for items decreases exponentially with time.

The integration approach has been studied by many researchers with different assumptions on the demand rate and the deterioration rate. These studies have thrown light on the need and importance of vendor-buyer integrated inventory system. Also these studies have shown that if the number of deliveries is decided in cooperation of both the vendor and the buyer, then the overall integrated cost can be minimized.

All type of items in the inventory may not deteriorate with time. Many researchers have developed inventory models in integrated approach for non-deteriorating items. Woo et al. (2001) studied a single-vendor multi-buyers integrated inventory model with constant demand and reduction in ordering cost. Shortages of inventoried item are not allowed. An optimal pricing and replenishment policy is developed by Yang and Wee (2003a) for a vendor-buyer integrated inventory system. A quantity discount strategy is considered to entice the buyer to order the items in large quantity for the benefits of integrated system. Khouja (2003) studied a three-stage supply chain consisting multiple firms at each stage and multi-customer in each firm. Darwish (2009) extended Khouja's (2003) three-stage multi-customer supply chain to n-stage multi-customer supply chain inventory model.

Ouyang et al. (2004) have developed integrated vendor-buyer model in two cases. In the first case, it is assumed that the lead time demand is stochastic and it follows a normal distribution. In the second case, the inventory model is solved by using the minimax distribution – free approach. Shortages are allowed during the lead time and it is shown that the lead time can be reduced at an added cost. Ben-Daya and Hariga (2004) developed a single vendor single buyer integrated production inventory model with stochastic demand and assumed that the lead time varies linearly with the lot size. Equal sized batch shipments from vendor to buyer is considered. Glock (2009) modified the model developed by Ben-Daya and Hariga (2004). In

this model, the author relaxed the assumption of equal sized batch shipment and considered shipment size increases by a fixed factor from batch to batch and showed that batch shipment of unequal size minimizes the total cost of the vendor-buyer integrated system. Hill and Omar (2006) developed a production and shipment policy for a single-vendor single-buyer with unequal shipment sizes based on the assumption that the unit stock holding costs increase as stock moves down in the supply chain. Hoque and Goyal (2006) considered a heuristic solution procedure to develop a single-vendor single-buyer integrated inventory model under controllable lead time and shipment of items from vendor to buyer considered in both equal and unequal sizes. Chang et al. (2006) developed two models of an integrated single-vendor single-buyer inventory incorporating the reduction of lead time and ordering cost. The first model is developed when the ordering cost reduction and the lead time crashing cost are not related to each other where as the second model is developed when these two are linearly related to each other.

An alternative model where the integrated total cost consisting the transportation cost is developed by Hoque (2007) for a single-vendor single-buyer system under controllable lead time. The study involves both equal and unequal sized batch shipment from vendor to buyer. Jha and Shanker (2009) studied a two-echelon single-vendor single-buyer with stochastic demand and controllable lead time. Shortages are completely backordered. But instead of considering shortage cost in the total cost of the system, a service level constraint (stock-out level per cycle is bounded) on buyer is included in the model. Sajadieh and Jokar (2009) and Sajadieh et al. (2009) presented a single-vendor single-buyer integrated inventory model in two-stage under the assumption of stochastic lead time. Shortage of items is allowed and completely back ordered. Glock (2012) derived an inventory model for a single-vendor single-buyer integrated system with stochastic demand. Lead time is considered as a variable and it can be reduced by reducing the setup or production or transportation time. Wangsa and Wee (2017) studied an integrated single-vendor single-buyer inventory model with stochastic demand. Transportation cost which is a function of shipping weight, distance covered and transportation modes is considered in the total cost.

Siajadi et al. (2006) developed an integrated inventory model for a single-vendor multiple-buyer with multiple deliveries. Yang (2007) studied an integrated vendor-buyer inventory model for triangular fuzziness of annual demand and fuzzy adjustable production rate. Jalbar et al. (2007) developed an integrated inventory model for a single-vendor and two different buyers.

A fixed delivery cost is charged for each order for each buyer. Wee and Yang (2007) studied a 'leagile' (lean and agile) supply chain system for a single-vendor multi-buyers to obtain an optimal pricing and replenishment solution. Here vendor offers the price reduction to entice the buyers to order more quantity for the benefits of the whole inventory system. Ben-Daya and Al-Nassar (2008) developed a three layer supply chain production-inventory model for suppliers, manufacturers and retailers.. There may be more than one firm at each stage and the produced lot is sent in equal sized shipments to the adjacent downstream stage. Hoque (2008) studied a single-vendor multi-buyers integrated inventory system in three different variations. The author considered the items transferred from vendor to buyers in equally sized shipment batch in the first two models and unequal sized shipment batch in the third model.

Chung et al. (2008) studied a supply chain inventory system with forward-oriented material flow as well as reverse material flow. The reverse material flow consisting returning back of the used materials, remanufacturing and shipping to the retailer for resale. Glock (2011) developed a multiple-vendor single-buyer integrated inventory model for single-item with constant demand rate. Here, the buyer purchases the items from different vendors. Pasandideh et al. (2011) developed a two-level supply chain for a single-supplier single-retailer for several products and multi-constraints. The multi-constraints considered are the limited capacity for supplier's warehouse and limited number of orders. Shortages are allowed and completely backlogged.

Lin and Ho (2011) showed how to maximize the joint total profit per unit time by offering a quantity discount to the buyer when demand rate is a function of retail price. Barron et al. (2011) presented an arithmetic-geometric inequality approach to obtain the optimal inventory policy for the vendor-buyer integrated system. Hoque (2011) first developed a single-vendor multi-buyer integrated inventory model and later he considered the model for single-vendor single-buyer. Yen et al. (2012) obtained an optimal ordering policy for a supply chain system with two levels of trade credit and two distinct warehouses - one is own and the other one is for rent.

In a supply chain management, vendor dominates the entire system. As a part of this, vendor stores his products at the buyer's warehouse and the buyer has to pay the carrying cost for this inventory. This mechanism is well known as Consignment Stocking (CS) policy between vendor and buyer. Some researchers have developed their model under this CS policy. Zavanella and Zanoni (2009) developed an integrated one-vendor multi-buyer inventory

model under CS policy. Battini et al. (2010) studied a single-vendor multi-buyer integrated inventory model under CS policy. Numerical result shows that the CS policy reduces the total cost of the integrated system. Ohaiba et al. (2017) developed an integrated inventory model for a single-vendor single-buyer with a constant demand and constant lead time under CS policy. The model includes periodic inventory audit and in-transit inventory holding costs.

A production process need not always produce good items. Sometimes it can produce a certain number of defective items too because of chance and assignable causes. To ensure good quality, inspection of items produced must be considered. But there may be inspection errors also. Vendor-buyer integrated inventory models with defective items have been studied by many researchers. Ouyang et al. (2006) have investigated a vendor-buyer integrated inventory policy for defective items under three cases: crisp defective rate, triangular fuzzy defective rate and statistical fuzzy defective rate. Wu et al. (2007) studied an integrated vendor-buyer inventory system with controllable lead time and sublot sampled inspection policy adopted by buyer. Rezaei and Davoodi (2008) formulated the problem of supply chain for multiple suppliers of buyer's selection and multiple products with imperfect quality as a mixed integer programming model. Here all the suppliers have limited storage capacity and the buyer has a maximum storage space. All the imperfect items are sold at a discounted rate before the next replenishment. Ho et al. (2011) investigated the vendor-buyer integrated inventory model with the assumptions of the lot produced contains defective items and the lead time demand follows normal distribution. Buyer inspects all the items he has received and returns the defective items to the vendor.

Sana (2011) studied an integrated production-inventory model under three-layer supply chain consisting supplier, manufacturer and retailer for the process producing both perfect and imperfect quality of items. Hsu and Hsu (2012) considered imperfect quality of items and inspection errors in an integrated vendor-buyer production-inventory model. Ouyang et al. (2014) studied an integrated inventory model with a two-part trade credit policy and improvement in quality of items by investing capital on production process. Astanjin and Sajadieh (2017) developed two models – one model with constant demand and another model with price-dependent demand, in a supply chain system for an imperfect quality of items.

In supply-chain management system, the supplier offers some credit period to the customer to pay the purchasing cost with the expectation that

the customer will buy more items within the credit period. Because of this delay in payments, both the supplier and the customer will earn some interest and hence they can increase their own profit. Several research works have been done on this permissible delay in payments in vendor-buyer integrated system. Ho et al. (2008) considered 'two-part' strategy (cash discount and delay in payment) to get an optimal solution for an integrated supplier-buyer inventory model with price-sensitive demand. Chang et al. (2009) obtained an optimal solution of a pricing and ordering policy for an integrated vendor-buyer inventory system under trade credit policy and market demand is a decreasing function of the retail price. Huang (2010) and Huang et al. (2010) have developed integrated single-vendor single-buyer inventory models to determine the optimal policy under conditions of order-processing cost reduction and permissible delay in payments. Chen and Kang (2010a) considered vendor-buyer coordination to obtain the optimal solution under trade credit policy and imperfect quality of items. An integrated inventory model with permissible delay in payment and price-sensitive demand is studied by Chen and Kang (2010b) under two-level trade credit policy.

Teng et al. (2012) provided an optimal policy for vendor-buyer integrated inventory system under both non-cooperative and cooperative modes with trade credit financing policy. Giri and Roy (2013) studied an integrated single-vendor single-buyer inventory model where vendor offers a quantity discount for buyer to encourage to purchase more number of units. The purchased units are delivered in unequal size from vendor to buyer. Sarkar et al. (2014) developed an integrated inventory model with delay in payments and production of defective items.

Integration approach has been studied by several researchers for deteriorating item also. Some items deteriorate constantly with time, while deterioration of some other items could be modelled with probability distribution. Yang and Wee (2000) obtained an optimal economic ordering policy for a single-vendor single-buyer model with constant rates of production, demand and deterioration. Numerical example showed that the integration approach has reduced total cost of the system compared with the independent decision approach. Yang and Wee (2002) developed a production-inventory integrated model for a single-vendor multi-buyers with a constant rate of production, demand and deterioration. In another paper, the authors (2006) have shown that the total profit of the whole inventory system for deteriorating items can be maximized under the collaboration of vendor and buyer with permissible delay in payment. They have incorporated a negotiation factor to

balance the extra profit sharing between the two players according to their contribution. Zanoni and Zavanella (2007) considered a single-vendor single-buyer integrated inventory model for perishable goods where total integrated cost included transportation cost. Optimal solution is obtained using mixed integer linear programming.

Wee et al. (2004) have analysed an integrated two stage inventory model for Weibull deteriorating items by assuming a constant demand rate and limited retailer storage space. Lo et al. (2007) have presented an integrated production inventory model by assuming a varying rate of deterioration (Weibull distribution deterioration), partial back ordering, inflation, imperfect production processes and multiple deliveries. They have used the discounted cash flow and classical optimization technique to derive the optimal solution. Chung and Wee (2008b) have investigated an integrated production inventory model considering the pricing policy, imperfect production, inspection planning, warranty period, stock level dependent demand with the Weibull deterioration, partial back order and inflation.

Extensive research has been conducted regarding the producer-buyer relationship under JIT (Just-in-Time) environment. Yang and Wee (2003b) developed a multi-lot-size production inventory model for a single producer multi-buyers under JIT lot-splitting flow with constant production, demand and deterioration rate. The lot-splitting flow carried out in two layers- material flow from supplier to producer and product flow from producer to multi-buyer. Yang and Pan (2004) have proposed an integrated inventory model involving deterministic variable lead time and quality improvement investment with normally distributed lead time demand under JIT purchasing model without shortages. Yang et al. (2007) derived an optimal ordering policy for a single-vendor single-buyer under JIT environment. An extension of Yang and Pan's (2004) model has been studied by Ouyang et al. (2007). The model allows for shortages and considers reorder point as one of the decision variables which improves the system performance and annual joint total expected cost. Chung and Wee (2007) derived an integrated single-vendor single-buyer inventory model for deteriorating items under JIT multiple deliveries. Total cost is incorporated by transportation cost, inspection cost and the cost of less flexibility.

Chung and Wee (2008a) developed a vendor-buyer integrated inventory model for deteriorating items under JIT multiple deliveries. Jong and Wee(2008) have developed an integrated single-buyer single-supplier deteriorating model in a JIT environment and have considered the costs and benefits of imple-

menting JIT delivery. Chen and Sarker (2010) developed a different supply chain model for a multi-vendor integrated procurement-production inventory system. Several vendors supply different components/parts to the assembly system on demand under JIT procurement system. Total cost consists of delivery and shared transportation cost. Shah (2011) has considered an integrated inventory model for single supplier and single buyer under JIT deliveries when demand is stock dependent and the units in inventory deteriorate at a constant rate. Teng et al. (2011) have obtained the optimal solution for the integrated vendor-buyer inventory system using an arithmetic-geometric inequality under JIT delivery. Shortages are completely backlogged. Roy et al. ((2012) have framed an integrated producer-buyer inventory model with constant demand and small lot size in two different production environment: an EMQ (Economic Manufacturing Quantity) and a JIT by allowing shortages for the buyer and backlogged at the beginning of the buyer's cycle.

Some authors studied vendor-buyer integrated inventory models with ramp type demand and trapezoidal type demand. Shah et al. (2013) developed an inventory model for vendor buyer system with variable deterioration rate. They have assumed trapezoidal demand rate for both vendor and buyer. Aarya and Kumar (2015) developed a single vendor single buyer integrated production inventory model with ramp type demand rate for vendor and constant demand rate for buyer. They have considered three parameter Weibull deterioration, variable holding cost, inflation and multiple deliveries.

Several authors have considered vendor-buyer integrated inventory models, but a few of them considered models with shortages. Singh and Chandramouli (2011) developed a single-vendor, multi-buyers production-inventory policy with shortages for buyers and partial backlogging. They considered a constant production, variable demand rate and Weibull deterioration rate. Singh and Singh (2013) developed a vendor-buyer integrated model for deteriorating items with complete backlogging of shortages for buyers under fuzzy and inflationary environment.

Objectives of the study

The review of literature on inventory models/systems has revealed several openings to do further studies. Most of the researchers have developed integrated vendor-buyer inventory systems for deteriorating items with demand pattern as constant, stock-dependent, price-sensitive, stochastic demand etc., and not considered ramp type demand and trapezoidal type demand. But

in real life, demand for items such as newly launched electronic components, fashionable clothes, cosmetic products, automobiles etc. follows ramp type demand. For the present situation, because of technological improvement and digitalization, it is necessary to study the effects of ramp type demand on an integrated vendor-buyer inventory system.

As the demand increases, the production and stock of inventory in sufficient quantity to avoid shortages is rather difficult in an inventory system. Also in EOQ models, most of the researchers have showed that the inventory model with shortages and complete backlogging minimizes the total cost of the inventory system.

So in this thesis, we have focused on the development of inventory models on vendor-buyer integrated system under the assumption of:

- Stock level dependent demand and Weibull deterioration.
- Two phase ramp type demand and constant deterioration.
- Three phase ramp type demand and constant deterioration.
- Linearly increasing time dependent demand with constant deterioration and shortage for buyer with complete backlogging.

Purpose of studying integrated vendor-buyer system is to obtain an optimal solution such that the integrated total cost should be minimum. We consider model development, analytical approach to solve the model, development of solution procedure to obtain optimal solution numerically and sensitivity analysis of the optimum solution, under various situations/combinations of situations, mentioned above.

Summary of the thesis

This thesis contains five chapters, each chapter consisting of several sections containing the mathematical model for inventory system of vendor and buyer, cost components of vendor and buyer, integrated total cost function, numerical example, sensitivity analysis and observations based on sensitivity analysis.

Chapter 1 contains a brief introduction to the inventory system, consisting of basic inventory concepts - cost components, basic models involved,

general mathematical model and its solution, vendor-buyer relationship, literature survey on Economic Order Quantity models and vendor-buyer inventory models. Objectives of the study have also been provided in Chapter 1.

In Chapter 2, some of the demand patterns considered in literature have been elaborated. A brief explanation of stock-dependent demand, Weibull deterioration rate and general form of total cost of the integrated vendor-buyer inventory system have also been provided.

Chapter 2 describes an integrated vendor-buyer inventory system with stock-dependent demand rate and Weibull deterioration rate of items. The model has been studied under the assumption that production rate is proportional to the demand rate. Since it is stock-dependent demand, shortage of items is not considered for both the vendor and buyer. The lead time is zero or negligible.

Mathematical model and its solution for vendor's and buyer's inventory systems have been provided. Buyer's and vendor's relevant costs and integrated total cost expression of the system have been discussed. A procedure to obtain an optimal solution has also been provided. Since the integrated vendor-buyer inventory system consists of stock-dependent demand and Weibull deterioration, obtaining the closed form expression for the integrated total cost is complicated. Also, it is a function of four variables: number of deliveries from vendor to buyer, the production and non-production period and the delivery period. Hence, we have obtained the optimal solution by using pattern search procedure in Optimization Tool-MATLAB version R2011a. Results of numerical study have been presented. Sensitivity analysis carried out to study the effects of changes in various parameters on optimal solution, and observations drawn from the sensitivity analysis have also been provided.

Chapter 3 provides a study of an integrated vendor-buyer inventory system with two phase ramp type demand and constant deterioration rate. A brief introduction of two-phase ramp type demand and its functional form have been provided in this chapter. Items in the inventory deteriorate constantly over time. Since ramp type demand is considered for items which have a specific/short life span in the market, like fashion goods, shortages have not been allowed. Vendor's and buyer's inventory systems have been studied and buyer's and vendor's total costs have been derived. Integrated total cost has also been provided. It is a function of the number of shipments from vendor to buyer in two phases, the shipment schedule and the

cycle length. The objective of the problem is to determine the optimal values of these variables that minimize the integrated total cost. An algorithm to obtain the optimal solution of the system has been developed. The optimal solution has been obtained using pattern search procedure in Optimization Tool- MATLAB Version R2011a. Results of the numerical example, sensitivity analysis carried out on optimal solution and its observations have also been provided.

In chapter 4, we have elaborated an integrated vendor-buyer inventory system for the items which deteriorate constantly, having three phase ramp type demand rates. We have explained briefly three phase ramp type demand and its functional form. Literature review in the chapter 1 mentions several vendor-buyer integrated inventory models developed by many researchers under various assumptions on demand and deterioration rate. Shah et al. (2013) developed an inventory model for vendor-buyer system with different deterioration rates for both vendor and buyer. The authors have assumed trapezoidal demand rate for both vendor and buyer. But it has an error in the mathematical formulation of the model for buyer. We have considered the most general form of ramp type demand pattern for both vendor and buyer as in Panda et al. (2008) and shortages have not been allowed.

Vendor's and buyer's inventory systems, model development and analytical solutions have been provided in this chapter. Buyer's and vendor's total costs have been derived. Integrated total cost has been provided. It is a function of the number of shipments from vendor to buyer in three phases and the cycle time. The objective of the problem is to determine the optimal values of these variables that minimize the total cost of the system. An iterative procedure has been provided to obtain the optimal solution. We have implemented the iterative procedure using Optimization Tool-MATLAB Version R2011a. Numerical example and its result, sensitivity analysis and observations based on sensitivity analysis have also been included.

Chapter 5 describes vendor-buyer integrated production inventory system with constant deterioration and time varying demand, allowing shortages and complete backlogging.

Several researchers have developed models on Economic Order Quantity (EOQ) with different assumptions on demand and deterioration rate, with or without shortages, partial backlogging etc. Several authors have considered vendor-buyer integrated inventory models with different assumptions on demand and deterioration rate, but only a few of them considered models with shortages [Singh and Chandramouli (2011) and Singh and Singh (2013)].

But these two papers miss out on several information and there are some inconsistencies in the numerical example used for illustration of the models.

We have formulated and solved for a production-inventory problem of a vendor-buyer integrated system. We have considered constant rate of deterioration of items, and shortages are allowed for buyer with complete backlogging. Both demand and production rates are functions of time. Vendor's and buyer's inventory systems have been derived. Buyer's and vendor's total costs are given. Integrated total cost is also provided. One of the assumptions considered to develop the model for buyer is that the replenishments should be made at equal intervals of time throughout the cycle. Hence, total cost of the integrated system is a function of the number of replenishments from vendor to buyer, the time points where shortage of items starts to occur and the production length. Solution procedure in an algorithmic form to obtain the optimal solution has been provided. Numerical example and its results have been provided. We have obtained the optimal solution by using MATHEMATICA 11.1. Sensitivity analysis and observation based on sensitivity analysis have also been included in this chapter. Concluding remarks and scope for future work have also been provided in this chapter.

Content list of the thesis

Chapter 1. Introduction and review of literature

Chapter 2. Vendor-buyer integrated production-inventory model with Weibull deterioration and stock-dependent demand

Chapter 3. Integrated vendor-buyer inventory system with two phase ramp type demand and constant deterioration

Chapter 4. Integrated vendor-buyer inventory system with constant deterioration and three phase ramp type demand

Chapter 5. Integrated vendor-buyer production-inventory system with time-varying demand, constant deterioration and shortages

References

List of papers published/communicated for publication

1. Savitha and Achary, K.K., (2016), An integrated production-inventory model with Weibull deterioration and stock-dependent demand under

JIT production system, *International Journal of Science, Engineering and Technology Research (IJSETR)*, Vol.5, Issue 10, pp.3003–3008.

2. Savitha and Achary, K.K., (2017), A single-vendor single-buyer integrated inventory model for deteriorating items with ramp type demand, *Current Trends in Technology and Science*, Vol.VI, Issue VI, pp.806–811.

3. Achary, K.K. and Savitha, Optimal scheduling of delivery plans in an integrated vendor-buyer inventory model with constant deterioration and three phase ramp type demand - Communicated to *Acta Mathematicae Applicatae Sinica*.

4. Savitha and Achary, K.K., An integrated vendor-buyer production inventory system for deteriorating items with time varying demand and shortages for buyer - Communicated to *International Journal of Applied Engineering Research*.

References

[1] Aarya, D.D. and Kumar, M., (2015), Supply chain model with ramp type demand under planning horizon, *Indian Journal of Science and Technology*, Vol.8, No.15, pp.1–8.

[2] Aliyu, I. and Sani, B., (2018), An Inventory Model for Deteriorating Items with Generalised Exponential Decreasing Demand, Constant Holding Cost and Time-Varying Deterioration Rate, *American Journal of Operations Research*, Vol.8, pp.1–16.

[3] Amutha, R. and Chandrasekaran, E., (2013), An inventory model for deteriorating items with three parameter Weibull deterioration and price dependent demand, *International Journal of Engineering Research & Technology (IJERT)*. Vol.2, No.5, pp.1931–1935.

[4] Astanjin, M.B. and Sajadieh, M.S., (2017), Integrated production-inventory model with price-dependent demand, imperfect quality, and investment in quality and inspection, *AUT Journal of Modeling and Simulation*, Vol.49, No.1, pp.43–56.

[5] Barron, L.E.C., Wee, H.M. and Blos, M.F., (2011), Solving the vendor–buyer integrated inventory system with arithmetic–geometric inequality, *Mathematical and Computer Modelling* Vol.53, pp.991–997.

[6] Battini, D., Gunasekaran, A., Faccio, M., Persona, A. and Sgarbossa, F., (2010), Consignment stock inventory model in an integrated supply chain, *International Journal of Production Research*, Vol.48, No.2, pp.477–500.

[7] Ben-Daya, M. and Al-Nassar. A., (2008), An integrated inventory production system in a three-layer supply chain, *Production Planning & Control: The Management of Operations*, Vol.19, No.2, pp.97–104.

[8] Ben-Daya, M. and Hariga, M., (2004), Integrated single vendor single buyer model with stochastic demand and variable lead time, *International Journal of Production Economics*, Vol.92, pp.75–80.

[9] Chang, H.C., Ho, C.H., Ouyang, L.Y. and Su, C.H., (2009), The optimal pricing and ordering policy for an integrated inventory model when trade credit linked to order quantity, *Applied Mathematical Modelling*, Vol.33, pp.2978–2991.

[10] Chang, H.C., Ouyang, L.Y., Wu, K.S. and Ho, C.H., (2006), Integrated vendor–buyer cooperative inventory models with controllable lead time and ordering cost reduction, *European Journal of Operational Research*, Vol.170, pp.481–495.

[11] Chaudhary, R.R. and Sharma, V., (2013), Optimal inventory model with Weibull deterioration with trapezoidal demand and shortages, *International Journal of Engineering Research & Technology (IJERT)*, Vol.2, No.3, pp.1–10.

[12] Chen, L.H. and Kang, F.S., (2010a), Coordination between vendor and buyer considering trade credit and items of imperfect quality, *International Journal of Production Economics*, Vol.123, pp.52–61.

[13] Chen, L.H. and Kang, F.S., (2010b), Integrated inventory models considering the two-level trade credit policy and a price-negotiation scheme, *European Journal of Operational Research*, Vol.205, pp.47–58.

[14] Chen, Z.X. and Sarker, B.R., (2010), Multi-vendor integrated procurement-production system under shared transportation and just-in-time delivery system, *Journal of the Operational Research Society*, Vol.61, pp.1654–1666.

[15] Cheng, M. and Wang, G., (2009), A note on the inventory model for deteriorating items with trapezoidal type demand rate, *Computers & Industrial Engineering*. Vol.56, pp.1296–1300.

[16] Cheng, M., Zhang, B. and Wang, G., (2011), Optimal policy for deteriorating items with trapezoidal type demand and partial backlogging, *Applied Mathematical Modelling*, Vol.35, pp.3552–3560.

[17] Chuang, K.W., Lin, C.N. and Lan, C.H., (2013), Order policy analysis for deteriorating inventory model with trapezoidal type demand rate, *Journal of Networks*. Vol.8, No.8, pp.1838–1844.

[18] Chung, C.J. and Wee, H.M., (2007), Optimal replenishment policy for an integrated supplier-buyer deteriorating inventory model considering multiple JIT delivery and other cost functions, *Asia-Pacific Journal of Operational Research*, Vol. 24, No.1, pp.125–145.

[19] Chung, C.J. and Wee, H.M., (2008a), Scheduling and replenishment plan for an integrated deteriorating inventory model with stock-dependent selling rate, *International Journal of Advanced Manufacturing Technology*, Vol.35, pp.665–679.

[20] Chung, C.J. and Wee, H.M., (2008b), An integrated production-inventory deteriorating model for pricing policy considering imperfect production, inspection planning and warranty-period and stock-level-dependent demand, *International Journal of Systems Science*, Vol.39, No.8, pp.823–837.

[21] Chung, S.L., Wee, H.M. and Yang, P.C., (2008), Optimal policy for a closed-loop supply chain inventory system with remanufacturing, *Mathematical and Computer Modelling*, Vol.48, pp.867–881.

[22] Darwish, M.A., (2009), Economic selection of process mean for single-vendor single-buyer supply chain, *European Journal of Operational Research*, Vol.199, pp.162–169.

[23] Giri, B.C. and Roy, B., (2013), A vendor–buyer integrated production-inventory model with quantity discount and unequal sized shipments, *International Journal of Operational Research*, Vol.16, No.1, pp.1–13.

[24] Glock, C.H., (2009), A comment: "Integrated single vendor-single buyer model with stochastic demand and variable lead time", *International Journal of Production Economics*, Vol.122, pp.790–792.

[25] Glock, C.H., (2011), A multiple-vendor single-buyer integrated inventory model with a variable number of vendors, *Computers and industrial Engineering*, Vol.60, pp.173–182.

[26] Glock, C.H., (2012), Lead time reduction strategies in a single-vendor–single-buyer integrated inventory model with lot size-dependent lead times and stochastic demand, *International Journal of Production Economics*, Vol.136, pp.37–44.

[27] Hariga, M., (1995), An EOQ model for deteriorating items with shortages and time - varying demand, *Journal of the Operational Research Society*, Vol.46, No.3, pp.398–404.

[28] Hill, R.M. and Omar, M., (2006), Another look at the single-vendor single-buyer integrated production-inventory problem, *International Journal of Production Research*, Vol.44, No.4, pp.791–800.

[29] Ho, C.H., Goyal, S.K., Ouyang, L.Y. and Wu, K.S., (2011), An integrated vendor-buyer inventory model with defective items and partial backlogging, *International Journal of Logistics Systems and Management*, Vol.8, No.4, pp.377–391.

[30] Ho, C.H., Ouyang, L.Y., and Su, C.H., (2008), Optimal pricing, shipment and payment policy for an integrated supplier–buyer inventory model with two-part trade credit, *European Journal of Operational Research*, Vol.187, pp.496–510.

[31] Hoque, M.A., (2007), An alternative model for integrated vendor–buyer inventory under controllable lead time and its heuristic solution, *International Journal of Systems Science*, Vol. 38, No. 6, pp.501–509.

[32] Hoque, M.A., (2008), Synchronization in the single-manufacturer multi-buyer integrated inventory supply chain, *European Journal of Operational Research*, Vol.188, pp.811–825.

[33] Hoque, M.A., (2011), Generalized single-vendor multi-buyer integrated inventory supply chain models with a better synchronization, *International Journal of Production Economics* Vol.131, pp.463–472.

[34] Hoque, M.A. and Goyal, S.K., (2006), A heuristic solution procedure for an integrated inventory system under controllable lead-time with equal or unequal sized batch shipments between a vendor and a buyer, *International Journal of Production Economics*, Vol.102, pp.217–225.

[35] Hsu, J.T. and Hsu, L.F., (2012), An integrated single-vendor single-buyer production-inventory model for items with imperfect quality and inspection errors, *International Journal of Industrial Engineering Computations*, Vol.3, No.5, pp.703–720.

[36] Huang, C.K., (2010), An integrated inventory model under conditions of order processing cost reduction and permissible delay in payments, *Applied Mathematical Modelling*, Vol.34, pp.1352–1359.

[37] Huang, C.K., Tsai, D.M., Wu, J.C. and Chung, K.J., (2010), An integrated vendor–buyer inventory model with order-processing cost reduction and permissible delay in payments, *European Journal of Operational Research*, Vol.202, pp.473–478.

[38] Jain, S. and Kumar, M., (2007), An EOQ Inventory Model with Ramp Type Demand, Weibull Distribution Deterioration and Starting with Shortage, *OPSEARCH*, Vol.44, No.3, pp.240–250.

[39] Jain, S. and Kumar, M., (2010), An EOQ inventory model for items with ramp type demand, three-parameter Weibull distribution deterioration and starting with shortage, *Yugoslav Journal of Operations Research*, Vol.20, No.2, pp.249–259.

[40] Jalbar, B.A., Jose, M.G. and Sicilia, J., (2007), An integrated inventory model for the single-vendor two-buyer problem, *International Journal of Production Economics*, Vol.108, pp.246–258.

[41] Jha, J.K. and Shanker, K., (2009), Two-echelon supply chain inventory model with controllable lead time and service level constraint, *Computers & Industrial Engineering*, Vol.57, pp.1096–1104.

[42] Jong, J.F. and Wee, H.M., (2008), A near optimal solution for integrated production inventory supplier-buyer deteriorating model considering JIT delivery batch, *International Journal of Computer Integrated Manufacturing*, Vol.21, No.3, pp.289–300.

[43] Khouja, M., (2003), Optimizing inventory decisions in a multi-stage multi-customer supply chain, *Transportation Research Part E*, Vol.39, pp.193–208.

[44] Lin, Y.J. and Ho, C.H., (2011), Integrated inventory model with quantity discount and price-sensitive demand, *Top*, Vol.19, pp.177–188.

[45] Lo, S.T., Wee, H.M. and Huang, W.C., (2007), An integrated production-inventory model with imperfect production processes and Weibull distribution deterioration under inflation, *International Journal of Production Economics*, Vol.106, pp. 248–260.

[46] Manna, S.K. and Chaudhuri, K.S., (2006), An EOQ model with ramp type demand rate, time dependent deterioration rate, unit production cost and shortages, *European Journal of Operational Research*, Vol.171, pp.557–566.

[47] Ohaiba, M.M., Hossain, M.S.J. and Sarker, B.R., (2017), Optimal consignment stocking policy for a vendor-buyer supply chain system with periodic inventory audit and in-transit holding cost, *International Journal of Inventory Research*, Vol. 4, Nos. 2/3, pp. 148–171.

[48] Ouyang, L.Y., Chuang, C.J., Ho, C.H. and Wu, C.W., (2014), An integrated inventory model with quality improvement and two-part credit policy, *TOP*, DOI 10.1007/s11750-013-0311-y.

[49] Ouyang, L.Y., Wu, K.S. and Ho, C.H., (2004), Integrated vendor-buyer cooperative models with stochastic demand in controllable lead time, *International Journal of Production Economics*, Vol.92, pp.255–266.

[50] Ouyang, L.Y., Wu, K.S. and Ho, C.H., (2006), Analysis of optimal vendor-buyer integrated inventory policy involving defective items, *International Journal of Advanced Manufacturing Technology*, Vol.29, pp.1232–1245.

[51] Ouyang, L.Y., Wu, K.S. and Ho, C.H., (2007), An Integrated vendor-buyer inventory model with quality improvement and lead time reduction, *International Journal of Production Economics*, Vol.108, pp.349–358.

[52] Papachristos, S. and Skouri, K., (2000), An optimal replenishment policy for deteriorating items with time-varying demand and partial-exponential type-backlogging, *Operations Research Letters*, Vol.27, pp.175–184.

[53] Panda, S., Saha, S., and Basu, M., (2013), Optimal pricing policy and lot-sizing for perishable inventory with price and time dependent ramp-type demand, *International Journal of Systems Science*. Vol.44, No.1, pp.127–138.

[54] Panda, S., Senapati, S. and Basu, M., (2008), Optimal replenishment policy for perishable seasonal products in a season with ramp-type time dependent demand, *Computers and Industrial Engineering*, Vol.54, pp.301–314.

[55] Pasandideh, S.H.R., Niaki, S.T.A. and Nia, A.R., (2011), A genetic algorithm for vendor managed inventory control system of multi-product multi-constraint economic order quantity model, *Expert Systems with Applications*, Vol.38, pp.2708–2716.

[56] Rezaei, J. and Davoodi, M., (2008), A deterministic, multi-item inventory model with supplier selection and imperfect quality, *Applied Mathematical Modelling*, Vol.32, pp.2106–2116.

[57] Roy, M., Sana, S. and Chaudhuri, K., (2012), An integrated producer-buyer relationship in the environment of EMQ and JIT production systems, *International Journal of Production Research*, Vol.50, No.19, pp.5597–5614.

[58] Sajadieh, M.S., and Jokar, M.R.A., (2009), An integrated vendor–buyer cooperative model under stochastic supply lead-time, *International Journal of Advanced Manufacturing Technology*, Vol.41, pp.1043–1050.

[59] Sajadieh, M.S., Jokar, M.R.A., and Modarres, M., (2009), Developing a coordinated vendor–buyer model in two-stage supply chains with stochastic lead-times, *Computers & Operations Research*, Vol.36, pp.2484–2489.

[60] Sana, S.S., (2011), A production-inventory model of imperfect quality products in a three-layer supply chain, *Decision Support Systems*, Vol.50, pp.539–547.

[61] Sarkar, B., Gupta, H., Chaudhuri K. and Goyal S.K., (2014), An integrated inventory model with variable lead time, defective units and delay in payments, *Applied Mathematics and Computation*, Vol.237, pp.650–658.

[62] Shah, N.H., (2011), Single Supplier-Buyer Integrated Inventory Model Under Multiple JIT Delivery and Stock-Dependent Demand, *Journal of Mathematical modelling and Algorithms*, Vol.10, pp.293–305.

[63] Shah, N.H., Digeshkumar, B. and Shah, D.B., (2013), Joint optimal policy for variable deteriorating inventory system of vendor-buyer ordering with trapezoidal demand, *British Journal of Applied Science & Technology*, Vol.3, No.1, pp.160–173.

[64] Siajadi, H., Ibrahim, R.N. and Lochert, P.B., (2006), A single-vendor multiple-buyer inventory model with a multiple-shipment policy, *International Journal of Advanced Manufacturing Technology*, Vol.27, pp.1030–1037.

[65] Singh, C. and Singh, S.R., (2013), Vendor-buyers relationship model for deteriorating items with shortages, fuzzy trapezoidal costs and inflation, *Yugoslav Journal of Operations Research*, Vol.23, No.1, pp.73–85.

[66] Singh, S. and Chandramouli, A.B., (2011), An integrated inventory model for deteriorating items with time-dependent demand and allowable shortages, *International Journal of Computational Science and Mathematics*, Vol.3, No.2, pp.237–243.

[67] Singh, S.R. and Sharma, S., (2013), A Global Optimizing Policy for Decaying Items with Ramp-Type Demand Rate under Two-Level Trade Credit Financing Taking Account of Preservation Technology, *Advances in Decision Sciences*, Vol.2013, pp.1–12.

[68] Sivazlian, B.D. and Stanfel, L.E., (1975), Analysis of Systems in Operations Research, *Prentice - Hall Inc.*

[69] Skouri, K., Konstantaras, I., Manna, S.K. and Chaudhuri, K.S., (2011a), Inventory models with ramp type demand rate, time dependent deterioration rate, unit production cost and shortages, *Annals of Operations Research*, Vol.191, No.1, pp.73–95.

[70] Skouri, K., Konstantaras, I., Papachristos, S. and Ganas, I., (2009), Inventory models with ramp type demand rate, partial backlogging and Weibull deterioration rate, *European Journal of Operational Research*, Vol.192, pp.79–92.

[71] Skouri, K., Konstantaras, I., Papachristos, S. and Teng, J.T., (2011b), Supply chain models for deteriorating products with ramp type demand rate under permissible delay in payments, *Expert Systems with Applications*, Vol.38, pp.14861–14869.

[72] Teng, J.T., Barrón L.E.C., and Lou, K.R., (2011), The economic lot size of the integrated vendor–buyer inventory system derived without derivatives: A simple derivation, *Applied Mathematics and Computation*, Vol.217, pp.5972–5977.

[73] Teng, J.T., Chang C.T., and Chern, M.S., (2012), Vendor–buyer inventory models with trade credit financing under both non-cooperative and integrated environments, *International Journal of Systems Science*, Vol.43, No.11, pp.2050–2061.

[74] Valliathal, M. and Uthayakumar, R., (2013), A study of inflation effects on an EOQ model for Weibull deteriorating/ameliorating items with ramp type of demand and shortages, *Yugoslav Journal of Operations Research*, Vol.23, No.3, pp.441–455.

[75] Wangsa, I.D. and Wee, H.M., (2017), An integrated vendor–buyer inventory model with transportation cost and stochastic demand, *International Journal of Systems Science: Operations & Logistics*, http://dx.doi.org/10.1080/23302674.2017.1296601, pp.1–15.

[76] Wee, H.M. and Law, S.T., (2001), Replenishment and pricing policy for deteriorating items taking into account the time value of money, *International Journal of Production Economics*, Vol.71, pp.213–220.

[77] Wee, H.M. and Yang, P.C., (2007), A mutual beneficial pricing strategy of an integrated vendor-buyers inventory system, *International Journal of Advanced Manufacturing Technology*, Vol.34, pp.179–187.

[78] Wee, H.M., Yu, J. and Law, S.T., (2004), Collaboration inventory system with limited resources and Weibull distribution deterioration, *Proceedings of the Fifth Asia Pacific Industrial Engineering and Management Systems Conference 2004*, pp.34.7.1–34.7.16.

[79] Woo, Y.Y., Hsu, S.L. and Wu, S., (2001), An integrated inventory model for a single vendor and multiple buyers with ordering cost reduction, *International Journal of Production Economics*, Vol.73, pp.203–215.

[80] Wu, J., Skouri, K., Teng, J.T., and Hu, Y., (2016), Two inventory systems with trapezoidal-type demand rate and time-dependent deterioration and backlogging, *Expert Systems With Applications*, Vol.46, pp.367–379.

[81] Wu, K.S., (2002), Deterministic inventory model for items with time varying demand, Weibull distribution deterioration and shortages. *Yugoslav Journal of Operations Research*, Vol.12, No.1, pp.61–71.

[82] Wu, K.S., Ouyang, L.Y. and Ho, C.H., (2007), Integrated vendor–buyer inventory system with sublot sampling inspection policy and controllable lead time, *International Journal of Systems Science*, Vol.38, No.4, pp.339–350.

[83] Yang, M.F., (2007), Optimal strategy for the integrated vendor-buyer inventory model with fuzzy annual demand and fuzzy adjustable production rate, *Journal of Applied Sciences*, Vol.7, No.7, pp.1025–1029.

[84] Yang, J.S. and Pan, J.C.H., (2004), Just-in-time purchasing: an integrated inventory model involving deterministic variable lead time and quality improvement investment, *International Journal of Production Research*, Vol.42, No.5, pp. 853–863.

[85] Yang, P.C. and Wee, H.M., (2000), Economic ordering policy of deteriorated item for vendor and buyer: An integrated approach, *Production Planning & Control: The Management of Operations*, Vol.11, No.5, pp.474–480.

[86] Yang, P.C. and Wee, H.M., (2002), A single-vendor and multiple-buyers production–inventory policy for a deteriorating item, *European Journal of Operational Research*, Vol.143, pp.570–581.

[87] Yang, P.C. and Wee, H.M., (2003a), Optimal strategy in vendor-buyer alliances with quantity discount, *International Journal of Computer Integrated Manufacturing*, Vol.16, No.6, pp.455–463.

[88] Yang, P.C. and Wee, H.M., (2003b), An integrated multi-lot-size production inventory model for deteriorating item, *Computers and Operations Research*, Vol.30, pp.671–682.

[89] Yang, P.C. and Wee, H.M., (2006), A collaborative inventory system with permissible delay in payment for deteriorating items, *Mathematical and Computer Modelling*, Vol.43, pp.209–221.

[90] Yang, P.C., Wee, H.M., and Yang, H.J., (2007), Global optimal policy for vendor–buyer integrated inventory system within just in time environment, *Journal of Global Optimization*, Vol.37, pp.505–511.

[91] Yen, G.F., Chung, K.J. and Chen, T.C., (2012), The optimal retailer's ordering policies with trade credit financing and limited storage capacity in the supply chain system, *International Journal of Systems Science*, Vol.43, No.11, pp.2144–2159.

[92] Zanoni, S. and Zavanella, L., (2007), Single-vendor single-buyer with integrated transport-inventory system: Models and heuristics in the case of perishable goods, *Computers & Industrial Engineering*, Vol.52, pp.107–123.

[93] Zavanella, L., and Zanoni, S., (2009), A one-vendor multi-buyer integrated production-inventory model: The 'Consignment Stock' case, *International Journal of Production Economics*, Vol.118, pp.225–232.

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